Title
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Journal
Environmental epigenetics, 5(4)

ISSN
2058-5888

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Publication Date
2019-10-01

DOI
10.1093/eep/dvz019

Peer reviewed

ENVIRONMENTAL EPIGENETICS

Environmental Epigenetics, 2019, 1–11

doi: 10.1093/eep/dvz019
Perspectives

PERSPECTIVES

Epigenetics in the public sphere: interdisciplinary perspectives

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Managing Editor: Isabelle Mansuy

Abstract

Despite the high public interest in epigenetics, few scholars have empirically investigated the forms, reasons and consequences of the public circulation of epigenetics. Using an original database focusing on 'lifestyle' or 'everyday' epigenetics, this article aims to promote an open-minded and interdisciplinary dialogue between the public appropriation of epigenetics and the current scientific state of the art. It raises three main questions: Are there any specific modes of circulation of epigenetics in the general public? Why does epigenetics seem so appealing to the public? Within the public repertoire of epigenetics, is it possible to identify some specific knowledge claims and, if so, given the current state of the art, what is their degree of accuracy? The article argues that the social diffusion of epigenetics frequently carries on beliefs and misconceptions about genetics and epigenetics. The social life of epigenetics fuels a collective 'illusion' of control and empowerment on the basis of which new markets expand. More unexpectedly, this article underlines the emergence of a new scientific culture, i.e. the 'scientification' of the cultural appropriation of epigenetics. Our analysis can inform the scientific community about the current and evolving state of the public representation of epigenetics and help it frame outreach activities.

Key words: epigenetics; interdisciplinarity; empowerment; public perception; belief; lifestyle; consumerism; knowledge claim; scientific culture; scientific popularization

The spectacular development of epigenetics since the early 2000s has rapidly generated a significant and constantly growing media coverage. From the famous 2010 front cover of *Time Magazine*—'Why your DNA isn't your destiny'—to the recurring science columns of *The New York Times*, *The Guardian* or *Le Monde* narrating in detail its latest advances, epigenetics has undeniably a high public profile.

Predictably, epigenetics' high profile has provoked contrasting reactions within the scientific community. While some scientists consider public visibility as a possible asset, particularly

Received 20 June 2019; **revised** 2 September 2019; **accepted** 18 September 2019

to ensure better access to research funding, others have expressed concerns about its modalities and possible consequences. They repeatedly pointed fingers at the media for disseminating their field as 'hype' [1], 'fashion' [2], or 'buzzword' [3] or more simply for oversimplifying scientific results [4]. The issue of 'oversimplification' is all the more acute since scientists themselves are generally well aware of the difficulties to convey the complexity of their field to the general public, as demonstrated recently with the viral NASA 'space genes' story during which the concepts of genome and epigenome have been widely misinterpreted [5].

More unexpectedly, the intensive coverage of epigenetic findings in newspapers [6], magazines [7], books [8], radio [9] or television [10] has contributed to the formation of an interpretative repertoire—i.e. recurrent verbal images, metaphors, figures of speech and modes of explanation—spreading into popular culture on a daily basis. The exact nature of this repertoire is of particular interest for the social scientists as it provides new resources for individuals and social groups to define themselves and others. The fear that epigenetics may not only be misinterpreted but also socially and politically misused is among the concerns that scientists most frequently express [11].

This article aims to promote an open-minded and interdisciplinary dialogue between the public discourse on epigenetics and the current scientific state of the art. It raises three main questions: Are there any specific modes of circulation of epigenetics in the general public? Why does epigenetics seem so appealing to the public? Within the public repertoire of epigenetics, is it possible to identify some specific knowledge claims and, if so, given the current state of the art, what is their degree of accuracy? Using an original database focusing on 'everyday' epigenetics from 2013 to 2017, this article argues, not surprisingly, that the social diffusion of epigenetics findings frequently carries beliefs and misconceptions. It fuels a collective illusion of control and empowerment on the basis of which new markets expand. More unexpectedly, our database also comprises a wide range of accurate knowledge claims which unveil a new scientific culture in the making. This scientific culture mostly relates to the multiple potential of associations between material and social environments and epigenetic marks. Both public misconceptions about epigenetics and this emerging scientific culture among the general public should bring scientists to rethink how they publicly communicate about epigenetic research, in particular to review the novelty of epigenetics in relation to genetics, to temper expectations of control and empowerment, and to clarify whether scientific findings are about correlations or about causal relationships.

After presenting the state of the art and our methods, our analysis divides into three stages: a first, quantitative, approach of the database allows us to characterize the material. Then, we qualitatively analyse the two dimensions of the presentation of epigenetics present in the material: in opposition to genetics and as having social relevance. Finally, we bring into discussion this public understanding of epigenetics with the current state of the science by assessing the scientific merit of the claims made.

State of the Art

Despite the high public interest in epigenetics, few scholars have empirically investigated the forms, reasons and consequences of the public circulation of epigenetics. The existing studies explored the epigenetic repertoire through content analysis of documentary and radio broadcast [12], twitter accounts [13], national or international daily and weekly press [14–17] and focus groups [18]. The number of items and sources that have been studied remains limited: from 50 to 150 articles in journals such as *The Guardian* and *The Times*, *The New York Times* and *The Washington Post*, or in the German-speaking press. The main focus of the existing studies is on metaphors and 'causal narratives'. Results remain ambiguous, if not contradictory: on the one hand, the centrality of the '(re)programming' metaphor clearly demonstrates for some analysts that the public framing of epigenetics remains deterministic for example, 'the epigenetic approach is firmly embedded in traditional notion of genetic control' (p. 18) [12]; others consider that the replacement of 'grand' metaphors (such as 'book' or 'blueprint' of life for genetics) by smaller clusters of metaphorical expressions ('switch', 'mark', etc.) indicates that 'epigenetics is still waiting for its scientific "breakthroughs" and great debates which might "solidify" some of the epigenetic metaphors' (p. 214) [14]. This sense of instability and fluidity may also be found in one of the studies dealing with the link between representations of epigenetic causality (biological vs. environmental) and ideological bias (liberal vs. conservative). Confronted with the accumulation of mixed results, the author concludes that 'there is something about the science of epigenetics that complicates the conventional ideological dichotomizations, at least at this early stage in the emergence of the narrative' (p. 44) [16].

If most of the studies mentioned here—just like ours—adopt for various reasons a short-term historical perspective, one should neither naturalize these 'conventional dichotomizations' nor ignore that most of the contemporary narratives about epigenetics take place in a much longer history of claims about biology and 'human plasticity'. Although such an historical analysis is beyond the scope of this article, it is important to bear in mind that the contemporary public discourse on epigenetics may either reproduce, transform or strongly deviate from discourses previously produced on biology, at least since the late 19th century.

Methods and Data

The 2013–17 database built for this article is the product of a four-step process. First, we monitored public communication about epigenetics in the English-speaking media and social networks over 3 months. This preliminary phase made it possible to identify the most recurrent public narratives and the specific words and figures of speech used in these narratives. During this preliminary phase, we decided to focus on the most mundane dimensions of the epigenetic repertoire accessible in the media, what is sometimes described as 'everyday' epigenetics. In doing so, we deliberately left aside dimensions of the public discourse on epigenetics linked to exceptional events, such as the reinterpretation of historical traumatic experiences (war, genocide, slavery, etc.) [19], in order to focus on the less-commented on yet vast majority of available accounts connecting epigenetics to our most ordinary life. Second, we made a systematic extraction of data for the 2013–17 period using two general public sources: Europresse and Google advanced search. Europresse is a full-text press database featuring a wide selection of general-interest newspapers and specialized publications, as well as their archives [20]. In order to strike a balance between comprehensiveness and relevance, we adopted a mix-method: full-text search for Europresse and title search for Google advanced search. The research string used for GOOGLE and EUROPRESSE combined various declinations of the word 'epigenetic' (epigen* for epigenetic, epigenetics, epigenome, etc.) with

words or abbreviations identified during the first step (aging, beauty, biohack*, coach*, conscious*, control, cook*, cosmetic*, cream, diet, EFT, emotion*, empower*, energy, enhance*, freedom, keto*, medicine, meditation, menu, mind*, mind-body, paleo*, relaxation, sauna, serum, shampoo, skincare, sleep, spa, stress, tai, chi, vegetables, weight, wellbeing, wellness, yoga). Third, we refined the results of the raw extraction, ensuring that we kept only the relevant data for this research on public dissemination of epigenetics. Accordingly, we removed from the database scientific publications or reports, financial or business reports, press releases from research institutions, etc. At the end of this meticulous work, we arrived at an 841-item database almost equally balanced between the two sources: 438 Europresse items and 403 Google advanced search items. This 5-year database represents a total volume of more than one million words (1 157 255). Fourth, once refined, the database was standardized, coded and imported into the lexical analysis tools (Iramuteq© [21] and TXM© [22]). Each item has been identified on the basis of a number of variables, namely, format (blog, press or website), dominant modality of communication (information or commercial) and main target audience (public or professional). In accordance with our goals, our database is oriented mostly toward the general public: 90% of the items in 2013, 75% in 2017. Due to its origin (Google, Europresse) but also to our initial research strategy, this database has a strong Eurocentric bias: it gives a high visibility to a public discourse informed by Euro-American understandings of the science and of its mundane uses. It is important to note that due to content of the database, there is an under-representation of non-Western and non-English speaking countries. Recent studies have suggested possible differences of representations of epigenetics between Western and non-Western areas, although these suggestions should be formalized through comparative empirical investigation.

Words and Classes

Textual analysis tools were used to provide an initial global description of our data. Computer-assisted analysis of textual data involves multidimensional statistical analysis of texts, with frequency and specificity measurements, factor analysis of correspondence and automatic classification [23, 24]. We focus here on the two main results of this analysis.

The correspondence analysis chart in Fig. 1 makes visible that our database aggregates in an unequal proportion four main distinct lexical classes: scientific, medical, commercial and personal. The latter class, on the bottom left part of the chart, is the most prominent one (41.0%): epigenetics appears mostly in the database as 'personal knowledge' and/or 'personal practice'. It is about 'start[ing]' to 'think' and 'act' on a 'daily' basis. It invites individuals to take care of their own 'emotions', 'thoughts' and 'beliefs'. Epigenetics motivates them to 'enhance' their 'consciousness' and to 'understand' the course of 'life' or 'destiny'. Overall, this class mixes practical and 'philosophical' elements related to personal development. The second most prominent class, on the upper right part of the chart, is made up of medical terms (29.3%). In the database, epigenetics relates to health concerns, disease prevention and therapy. It focuses on 'health', 'health risks', 'diseases' such as 'cancer', 'diabetes', 'obesity', etc., and the various dimensions of the body that are directly or indirectly affected by the disease: 'cell', 'immune system', 'hormones', 'blood', etc. Science, on the bottom right part of the chart, appears as the third main class (18.2%). The lexical units of this class stem from the available scientific literature. Most of the public communication about epigenetics implies producing some pedagogical content about the biological entities and 'mechanisms' that are involved: 'gene', 'DNA', 'expression', 'histone', 'methylation', etc. These terms are also frequently used by authors to provide a general definition of epigenetics as an area of research.

Finally, the fourth and least prominent class (11.5%) present in the database focuses on the commercial and marketing dimensions of epigenetics. As with genetics in the 1990s, the increasing public interest for epigenetics since the early 2010s coincides with the emergence of a new 'industry' creating new 'products' (creams, cookbooks, etc.) and a new 'market' with a strong commercial presence on the web. Epigenetics here is about 'launching' 'institute', 'center' or 'department' providing 'consumers' with a diverse array of 'services' or customized 'wellness' and 'coaching' programs. In our database, this commercial dimension of the public discourse on epigenetics has increased from 35% of the items in 2013 to almost 50% in 2017.

The second general point that can be drawn from the textual analysis is the importance of the mode of communication on the content itself: medium matters. Epigenetics is not presented in the same way or with the same focus point in the press or in a blog, or whether the communication aims to inform the general public or to sell a specific product. To give a sense of these multiple variations, Table 1 lists the top 20 meaningful words (active forms) in our database by decreasing order of frequency: Gene, Health, Diet, etc. For each top word a score of specificity was computed for five modalities (blog, press, website, commercial, information) and was visually represented on a color scale (red to green). To make it easily readable, this visual representation draws attention to the most contrasted boxes: The greener the box is, the more the word is specific to the modality observed.

Without providing an exhaustive reading of Table 1, a few points should be underlined. It is for example noteworthy that the words 'diet', 'person', 'eat', or 'paleo' are specific to a communication made in blogs and not in the press. Even if this requires systematic verification, it suggests that part of the lexical class of personal development previously discussed is primarily produced in and circulates through blogs. For all media, the question of the novelty of the knowledge or the findings seems particularly relevant. The newness of the field of epigenetics, although it is now quite relative, is one of its defining features for the general public. In the press, this novelty is systematically valued and defined as a condition for public dissemination. The theme of childhood (with the word 'child', closely linked to terms such as 'mother', 'development', 'birth', 'birthweight', etc.) is also specific to the press. It suggests that press coverage of epigenetics deals a lot with the biology of development and the intergenerational or transgenerational dimensions of epigenetics. Finally, the table shows that the commercial communication produced around epigenetics puts a considerable stress on nutrition ('food', 'eat', 'paleo') and 'body' or 'skincare', whereas the informational mode lays a strong emphasis on 'cancer' and 'risks'.

While this lexicometric approach helps us to identify some of the key general features of our database, an in-depth analysis requires a more qualitative approach. Two main axes capture crucial aspects of the public circulation of epigenetics: the genetics–epigenetics relationship and the perceived utility of epigenetics for the lay public.

Epigenetics against Genetics

The available studies focusing on the representations of epigenetics within the scientific community [25–27] have shown

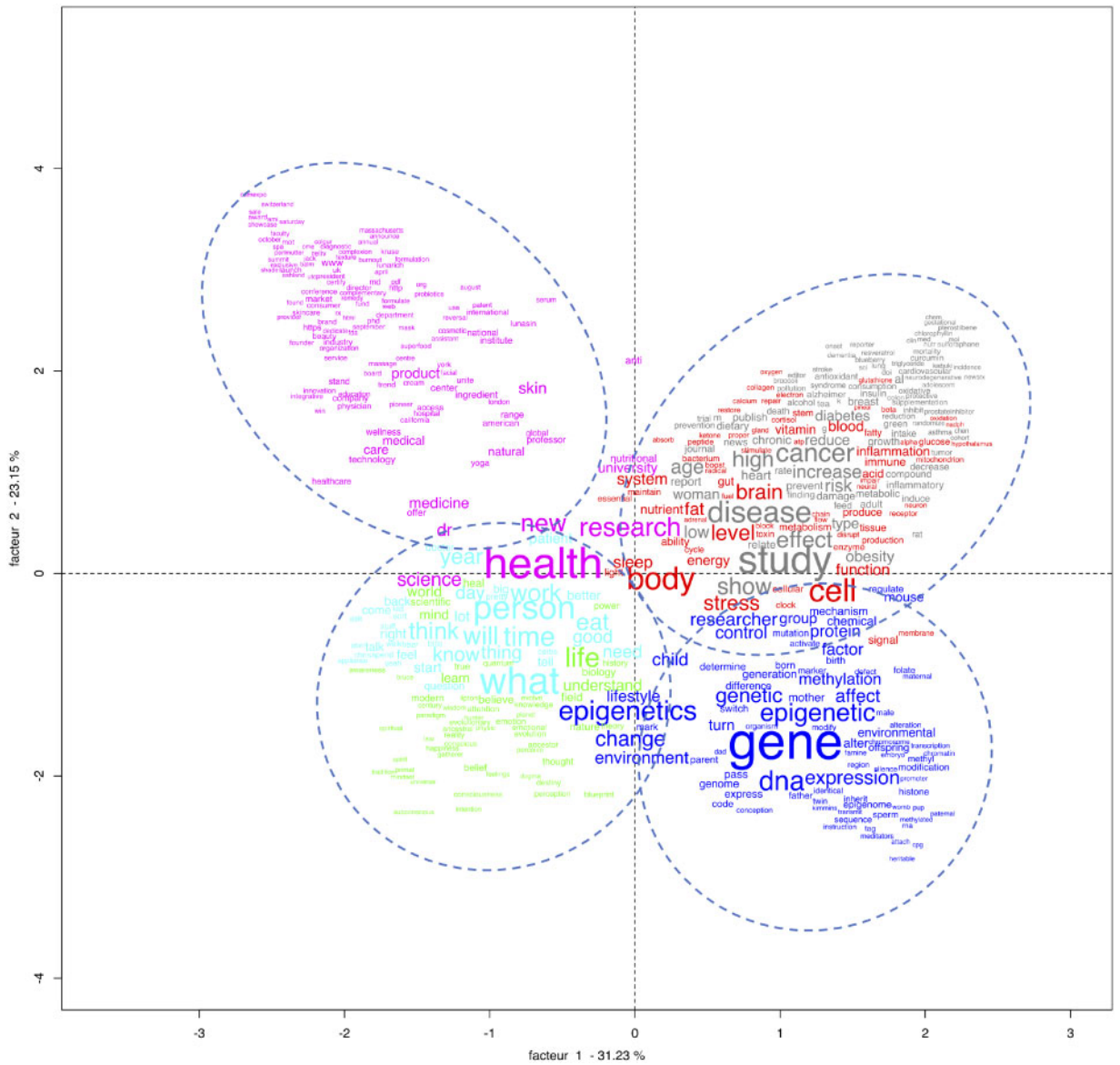

Figure 1: correspondence factor analysis (CFA) of classes produced by descending hierarchical classification (DCA). Size of the character proportional to frequency by class—horizontal axis, factor 1: 31.23%—vertical axis, factor 2: 23.15%

that it remains highly divided about the exact definition of epigenetics [28] and its relationship to genetics. For some, such as the scientist interviewed by Kasia Tolwinski (specialist in the area of science and technology studies), epigenetics 'it's just genetics. I don't even think it's on the edge. I think it's under! Because don't forget that even these epigenetic marks, the ability of epigenetic marks to exist, is controlled by genetics [. . .]. Epigenetics is subservient to the genome' (p. 375) [25]. For others, genetics and epigenetics are distinct but complementary approaches: 'purely genetic studies of common disease that ignore epigenetics are limited in their power, but also purely epigenetic studies that ignore genetics are also incomplete. Both are important and they are closely related' [29]. Finally, others view epigenetics as a part of a global 'paradigm shift': epigenetics is described as 'shifting the genetic paradigm (. . .) Genetic determinism is part of the story, but it's not the whole story. It turns out the environment has a major impact on biology' [30]. Although it could be assumed that the general public is, correspondingly, exposed to heterogeneous representations of epigenetics, the analysis of our database reveals quite the opposite. The representation is indeed much more homogeneous. It is mostly constructed through strong opposition lines to genetics. We now briefly analyze it following the three most salient lines of opposition. In the sections below the item id. enclosed in square brackets refers to the id. of the corresponding document in our database. For each item we also describe the type of media (press, blog, website) and its main aim (commercial or information).

New vs. Old

In the overwhelming majority of cases, epigenetics is discussed in our database as a 'new' and potentially 'revolutionary' science in comparison with the 'established' and 'old' genetics. Epigenetics is frequently described as being 'in its early days' [id_466, international press, information], 'in its infancy' [id_8, fitness blog, commercial], or as 'the latest discovery in the

Table 1: top 20 active forms and scores of specificity by modalities (format: blog, press, website; mode: commercial, information) – scale of specificity by color with score measured >= 50 (contrasted green) as highly specific and score measured <= −50 (contrasted red) as highly unspecific.

			Format		Mode	
Active forms (n=20)	Freq.	Blog	Press	Website	Commercial	Information
Gene	4619					
Health	3442					
Diet	3245					
Cell	2789					
Food	2559					
Person	2432					
Body	2220					
Disease	2197					
Cancer	2131					
Eat	1727					
New	1628					
Brain	1398					
Stress	1359					
Age	1283					
Sleep	1076					
Child	1057					
Skin	1047					
Paleo	1022					
Risk	1003					
Environnement	926					
-50	-20	-10	0	10	20	50

science of DNA' [id_106, yoga therapy website, commercial], and as 'growing exponentially' [id_138, foundation website, information], or 'poised to explode' [id_644, nutrition blog, commercial]. Despite the field of epigenetics in fact not being as young as is generally suggested in the database, the alleged novelty plays as a condition for public dissemination. Epigenetics is hailed not only as an interesting new development of science but as the 'future' or even an ongoing 'revolution': Epigenetics 'is turning what we've long held true about biological destiny upside down' [id_177, nutrition blog, commercial]. This expected revolution over genetics peaks in the perception of epigenetics as being able to bridge realms that have traditionally remained separated, be it nature vs. nurture—'epigenetics is a way to bridge the gap between two different viewpoints of evolution' [id_97, international press, information]—life sciences vs. social sciences—'epigenetics might ultimately become the organizing system that ties together hard science with social science' [id_138, foundation website, information]—or science vs. religion—'epigenetics is a new scientific breakthrough which shows that science is finally catching up with the Bible' [id_703, Christian science website, information].

Active vs. Passive

The epigenome is presented as the place of change and personal enhancement, while genes are portrayed as fixed and passive. This is in particular expressed in our database by the use of metaphors that reattribute to epigenetics

anthropomorphic features that used to be attached to genes, conceived as the source of agency in life processes. Here, agency and intelligence are projected onto epigenetic entities and processes, while genes are treated as passive or 'rather "dumb"' [id_133, health center website, commercial]. Epigenetics is explained as the intentional and intelligent ('smart') agent that was overlooked in the canonical account of genetics, the agent that is required to interpret and execute the code, read the book, follow the blueprint, the recipe or the map or interpret the music. 'Genes are equivalent to blueprints; epigenetics is the contractor. They change the assembly, the structure'. [id_101, lifestyle coach website, commercial] 'If a section of a person's genetic code were a cookie recipe, gene expression would refer to how many cookies, if any, a cook makes with the recipe'. [id_324, medical news website, information] 'You are the "driver" of your genetic roadmap'. [id_135, spiritual health website, information] 'Genes are the unique song of you, but epigenomes decide how that music is played over generations'. [id_1, international press, information] 'The notes are the genes, but the conductor and the musicians decide how fast and loud to play, which instruments are used, and how many'. [id_120, personal blog, commercial] Finally, the dynamics and presumed actionability of epigenetics come in the lexical field of action verbs that denote transformative actions such as 'rewrite', 'reprogram', 'reboot' the genes, as well as the ubiquitous metaphor of the 'switch'. The epigenome controls the expression of genes like a switch turns the light on or off: 'Methyl groups act as an on-off switch that turn a gene on or off. Histones, on the other hand, act like a dimmer switch, regulating gene activity up or down. It's thought that we have four million of these switches that are triggered by lifestyle and environmental factors'. [id_130, natural therapies website, information] This metaphor highlights a key feature of interest of the public, that is, the reversibility of epigenetic changes.

Open vs. Closed

A third ordinary line of opposition between epigenetics and genetics relates to the role of environment. Whereas genetics is described as hermetic or impervious to any environmental influence, epigenetics introduces a form of openness and environmental porosity: 'What is Epigenetics? The Impact of the Environment on Your Genes'. The term 'environment' is generally used in a vague and very flexible way, broadly denoting 'everything outside yourself' [id_5, nutrition website, information] with varying assumptions of what this encompasses. In a restricted sense, it means factors that are external to the individual body (e.g. 'our chemical environment'). In a looser sense, it means everything that surrounds genes, and includes 'lifestyle' as a large and non-exhaustive array of behaviours: 'Smoking, alcohol consumption, diet, physical activity, obesity, psychological stress, trauma, physical stress, infectious diseases, environmental pollutants, sun exposure, working night shift and countless other environmental factors can change our epigenomes'. [id_1, international press, information] The impact of the environment on the epigenome explains the expression of genes that are taken to be largely fixed: The epigenome is malleable and sensitive and responds to environmental 'cues', 'signals', 'factors', 'input'. 'Signals from our environment control if and how our genes are expressed'; 'Epigenetics has proven that our environment has the ability to regulate genetic expression'. [id_103, 'epigenetic coach' blog, commercial] A large power is now conferred upon the environment, able to 'influence the destiny of a cell' [id_11, well-being website, commercial], cause pathological effects on the body—'taking a toll on our bodies without us even realizing it' [id_817, well-being blog, commercial]—but also producing diversity—'the field of epigenetics is looking to explain the incredible diversity we see among human beings' [id_124, health center website, commercial]. Conversely, the mediation of the epigenome between the body and the environment offers a pathway to act on our own body (and the ones of our future children). Thanks to various techniques or products based on epigenetics such as meditation, diet or cream, it is promised that 'you can hack your own DNA' [id_219, national press, information], 'hack your own biology' [id_796, personal blog, commercial] or even 'hack your environment' [id_101, lifestyle coach website, commercial].

Epigenetics as Empowerment

Constructed by opposition to the 'old' genetics, the 'ever-new' science of epigenetics is also steadily depicted as giving the general public the capability to 'take control'. Whereas genetics assigns individuals to inevitable biological destinies, epigenetics allegedly demonstrates that 'DNA is not your destiny' [id_76, international press, information]. It provides individuals with the opportunity to act on their own biology, to control their health and more broadly to become 'masters of [their] destiny instead of victims of [their] genes' [id_114, lifestyle website, commercial]. This promise of empowerment, which can be critically interpreted as a powerful 'illusion of control', is closely related to the development of a set of products and services.

Healing Powers

Epigenetics is frequently portrayed in our database as revealing 'some of the root causes of health issues' [id_15, lifestyle website, commercial] and bringing novel therapeutic treatment, natural and non-invasive approaches that 'add depth and new science to alternative healing modalities and to mainstream medicine' [id_101, lifestyle coach website, commercial]. It shows in an unprecedented way the ordinary origins of health disorders that will occur later in life, such as metabolic diseases (diabetes, obesity, cardiovascular diseases) or cancer: every bite we eat, our lack of sleep, our exposure to stress, pollutants and toxins, our emotions and even our beliefs are described as potentially affecting the expression of our genetic material. Websites and blogs spread the promise that, by changing lifestyle choices, DNA damages can be 'reversed': 'The great news is that epigenetics can be reversed. This means that by triggering these genetic on/off 'switches' you can potentially change the course of your health, your life and how well you age'. [id_803, personal blog, commercial] In other words, specific daily practices could 'correct' the expression of a pool of candidate genes identified in the scientific literature. Many websites and blogs point to the therapeutic potential of daily individual practices. They highlight an array of remedies based, for example, on targeted foods or specific compounds found in foods or herbs; those are presented as beneficial to reduce tumor growth (like sulforaphane contained in vegetables) or inflammation (like curcumin). Good-quality sleep supports the immune system and regular exercise, or stress management techniques are beneficial to inflammation and stress level (potentially involved in a set of chronic diseases). Memory defects could also be improved by 'consuming high amount of fat, adequate protein and low carbohydrates' [id_779, science popularization website, information] able to 'open DNA and improve mental ability' [id_783, nutrition website, commercial]. Yoga, mindfulness, relaxation practices are

regularly mentioned: 'The foundations of yoga give great emphasis to improvement of various body systems, from digestion to nerve health. Some of this may be explained in the recent findings on the epigenetic activity of yoga practice. Yoga's capacity to modify genetic activity is one more demonstration of the benefits of these age-old practices and may support the oft-repeated claim that yoga extends both health-span and life-span'. [id_108, natural therapies website, information] Interestingly, this promise to prevent potential health issues by an individual upstream intervention, whatever the nature of this intervention may be (changing diet or sleeping habits, etc.), is not only for oneself but also for generations to come. Many articles draw the attention of parents-to-be to the transgenerational transmission not only of their genes but of some of their genetic expression states, inherited from their ancestors or generated by their lifestyle. Pregnant women are highly targeted by recommendations about their nutrition, their stress level, or 'poor-quality sleep' which 'during the third trimester of pregnancy can increase the odds of weight gain and metabolic abnormalities in offspring once they reach adulthood' [id_53, international press, information]. It is recurrently claimed that 'What a mother does while she is pregnant can impact on the epigenome of her developing baby' [id_1, international press, information] and even her state of mind should be considered as influential for fertility: 'Epigenetics is now demonstrating … how our thoughts and beliefs affect us at the cellular level. …Your mind can affect your ability to get pregnant on multiple levels'. [id_218, fertility institute website, information]

Selling Control

Over and over, it is repeatedly emphasized in our database that contrary to what was taught by modern science till lately, the genetics each of us inherited from our parents does not determine 'what we are'. Epigenetics is described as an area of research showing that 'we have a greater potential to affect who we are, how we are, and even what we are. The phrase 'it's genetic,' no longer means something is determined by forces beyond our control'. [id_97, international press, information] 'We have the power to catalyze DNA activation from within, no matter what our past' [id_697, lifestyle website, information]. In fact, the main aim of epigenetics in the public sphere seems to provide individuals with the power to 'control [their] fate'. With discoveries in the field of epigenetics, we now know from now on that genetic expression 'is in our hands' [id_770, well-being website, commercial]. It is easy to understand why this global promise of empowerment obtains a huge and positive resonance in the general public. It nourishes the illusion that any individual, whatever their social condition may be, is able to act positively on his or her life course through the accumulation of simple and ordinary actions. If this promise leaves in the shadow most of the structural variables over which most individuals have no hold, it is important to notice that it is closely related to the development of a set of products or services. Hence, we observe the increasing commercial dimension of the public communication on epigenetics since 2013. Epigenetic knowledge is frequently mentioned, for example, in coaching or stress management methods: 'Epigenetics is the field of study that looks at biological pathways and mechanisms that have the power to switch genes on and off. As a certified health and lifestyle coach, my philosophy is strongly influenced by this idea, as we have the power to alter our own lifestyle and gene expression'. [id_101, lifestyle coach website, commercial] Many self-help books and cookbooks are based on it: 'We are going to build a community cookbook of epi-paleo recipes (woo hoo!) … We've set up a special forum on the site for you to submit your recipes (by season, of course!)' [id_601, nutrition website, commercial] Skin-care products are 'revolutionized', not to mention the development of spas and well-being centers where customized programs and conferences are offered to teach good lifestyle choices for a happy, healthy, but also longer life: 'Fighting aging by targeting how your genes work is huge in premium skincare—see, for instance, the crazy expensive Epigenetics range … At a more affordable level, Olay have done a study of 'exceptional skin agers,' the lucky 8% who look at least 10 years younger than they are. The genes responsible for protecting skin work harder in these women, but the study found that's more down to nurture (things like hydration and sun exposure) than nature'. [id_54, national press, information]

A Scientific Culture in the Making

Many press and blog headlines make bold assertions about how environment and lifestyle change our biology and our health, for instance: 'Thoughts and perspectives can affect your genes' [id_187, medical website, commercial]; 'It's official! Meditation does have health benefits' [id_229, health news website, information]; 'Every little bite of food can alter gene expression' [id_647, fitness website, commercial]; and 'You Are What Your Mother and Father (and Grandmothers and Grandfathers) Ate' [id_358, national press, information]. Social science scholars have criticized the media for being far less cautious than scientists and for spreading the idea that environment and lifestyle have direct, unbuffered effects on the biology of individuals through epigenetics. In this final section, we question this alleged discrepancy between the scientific literature and the media uses of epigenetics findings by investigating which scientific knowledge nurtures the knowledge claims made in the public sphere, beyond the sensational reporting of epigenetics noticeable in its headlines.

Scientific concepts that are closely associated with epigenetics research were not highly represented in our database: The lexical class which gathers scientific terms represents only 18.2% of the database (see 'Words and Classes' section). At the same time, however, references to biological entities and mechanisms are scattered all across the database, suggesting a certain degree of 'scientification' of the cultural appropriation of epigenetics. The notion of 'scientificization' used here not only refers to the growing dissemination of the scientific lexical class in the public discourse, but more importantly to a general process whereby the reference to this latter class becomes a source of legitimation for non-scientific activities. For instance, the term 'DNA' appears in 424 articles (with a total of 1966 references) and the term 'expression'—referring to 'gene expression'—appears in 363 articles (total of 889 references). There are also 1024 references to 'DNA methylation' (in 146 articles), by far the most frequently mentioned epigenetic mechanism. Histone modifications and RNAs respectively appear in 224 and 125 references.

We distinguish between two types of knowledge claims. As expected, a first type of knowledge claims does not build on the state of the art in epigenetic research; rather, it uses epigenetics as a means to gain scientific credibility. These knowledge claims abound in our database. They confirm the view that there is a significant gap between the actual epigenetic research and its public reception. More surprisingly, a second type of knowledge claims is based on an accurate account of recent research in epigenetics. In this case, there is no substantive

difference between these knowledge claims and statements made in the scientific literature. They display some of the same limitations including a propensity to conflate correlation and causation. Thus, inaccuracies or extrapolations observed within the public domain, even if magnified, ultimately mirror some pitfalls of the scientific field.

Distorting Epigenetics

Many knowledge claims confirm concerns that the media and the general public are still relatively poorly informed about current research in epigenetics, and that they use it to endorse their preexisting views on how environment and practices leave a straightforward biological imprint. Such knowledge claims are vague, merely mentioning biological entities and mechanisms such as 'gene expression', 'epigenetic change', 'epigenetic modifications' and 'epigenetic mechanisms'. They tend to link epigenetic changes (most often restricted to DNA methylation) to changes in 'gene expression' without specifying for example how epigenetic modifications have been measured, whether they are substantial, which genes are involved and whether gene expression levels have increased or decreased: 'The lack of sleep may increase DNA methylation, which can suddenly activate the expression of risky genes, like cancer-causing tumor growth genes.' [id_18, medical website, commercial] In addition, they do not specify the biological links between gene expression and health status but talk about the importance of gene expression for preventing disease risks linked with e.g. 'cell communication,' 'inflammation,' 'molecular damage' or 'cellular aging.' These vague knowledge claims are made to support commonsense knowledge about how environment and practices affect health—'every little bite of food can alter gene expression and affect health to affect gene expression and promote optimal health' [id_146, fitness website, commercial]; to demonstrate the biological benefits of practices such as mindfulness meditation: 'This outcome provides proof that mindfulness practice can lead to epigenetic alterations of the genome, according to the researchers' [id_109, science popularization website, information]; lastly, to promote the merits of a dietary supplement: 'The soy peptide lunasin is the first dietary ingredients identified to affect gene expression and promote optimal health at the epigenetic level' [id_614, nutrition website, commercial]. These claims remain largely unsubstantiated by scientific evidence and mostly speculative. They tend to refer to a hypothetical emerging scientific consensus without engaging with specific studies. Alternatively, some vague knowledge claims are backed by references to unrelated studies, often published in well-known scientific journals, in order to give scientific legitimacy to the claim. For example, the claim that 'thoughts, feelings, emotions, diet and other lifestyle factors exert epigenetic influences every minute of every day, playing a central role in aging and disease' [id_841, fitness website, commercial] is attached to a reference to a GWAS study that identified genetic loci that correlate with three aspects of mood: well-being, depressive symptoms and neuroticism [31] but does not involve nor refer to the epigenome.

Mirroring Science

In a smaller but significant number of knowledge claims, the public discourse gives an accurate account of recent research in epigenetics. These knowledge claims rely on research done on the whole range of epigenetic modifications: DNA methylation, histone modifications and small RNAs. They refer to specific biological mechanisms through which environment and practices might influence our health. In particular, they focus on a small set of genes which arguably play a role in a large range of biological processes such as cell differentiation and development and inflammatory responses (e.g. references to HDAC genes, RIPK genes, COX genes): 'One study looked at rats with three days of sleep deprivation. They found that sleep loss decreased histone acetylation levels and increased HDAC2 expression.' [id_18, medical information website, commercial] These knowledge claims are often made to support very specific expectations toward epigenetics: 'Eating vegetables containing sulforaphane may change your genes … Sulforaphane induces a protein called Nrf2, which has beneficial antioxidant and detoxifying effects' [id_402, nutrition blog, information]; 'The nutritional stress of the grandparents was likely passed down via epigenetic marks—these can be chemical additions on protein that wrap up DNA, methyl groups that change the structure of DNA once attached, or molecules called small RNAs.' [id_396, science popularization website, information] Lastly, they usually specifically report on recently published scientific studies, either by citing the relevant publications or by interviewing their authors: 'After three months, the researchers compared muscle biopsy samples from active and less active legs and found that exercise changed DNA methylation and gene expression. … The study also highlighted the importance of enhancers in the exercise response. Enhancers are regulatory DNA sequences that control genes from a distance, unlike promoters, which are adjacent to the genes they control. "We found little difference in promoters," says Lindholm. "Most changes were in enhancers".' [id_04, science popularization website, information] As this public discourse on epigenetics finds its root in the scientific literature, it shares the same basic tendencies: a predominant taste for correlative claims, a relative confusion between correlation and causation, and a frequent lack of demonstrating cause-effect relationships.

First, the predominance of correlative claims. Although headlines tend to imply that epigenetics provides straightforward biological explanations of how environments impact health, they mostly rely on claims of associations (394 references), links (72 references) and correlations (112 references) between environmental exposures and the epigenetic machinery, or between this machinery and health status: 'Tea drinking for women was associated with epigenetic changes in 28 different gene regions known to interact with cancer or estrogen metabolism.' [id_823, international press, information]; 'To the best of our knowledge, this is the first paper that shows rapid alterations in gene expression within subjects associated with mindfulness meditation practice' [id_231, science popularization website, information]. The predominance of correlative claims in our database echoes the large number of mostly correlative studies in the scientific literature. Indeed, one central aspect of the epigenome that fosters a large number of correlative claims is its ability to be highly responsive to environmental changes. Studies have examined a very large number of environmental factors that may be acting via epigenetic means including stress [32], nutrition [33], exercise [34], sleep [35], altitude [36], environmental chemicals [37] and many others. The establishment of correlations has also been facilitated by the equally large number of epigenetic modifications described to date, approximating 500, and including at least three types of DNA methylations (5-methyl cytosine, 5-hydroxy-methyl cytosine and other degradation products, N6-methyl adenosine), 494 types of histone modifications [34], in addition to many non-coding RNAs [35]. As these marks are distributed throughout the genome in a cell-

type specific way and also change over time, the probability that any of these measures can be associated with a given environmental change is high.

Second, the public discourse on epigenetics shares with scientific sources the overextension of correlative claims toward causation. In our database, the distinction between correlation and causation tends to become fuzzy, with mentions of the 'role' of epigenetics in individual responses to environmental cues such as: 'DNA methylation plays an important role in our body's response to stress' [id_18, medical website, commercial] or 'Recent research suggests that epigenetics plays a key role in the early nutritional programming of long-term cognition and mental health' [id_56, nutrition website, information]. A conflation between correlation and causation in the public sphere is understandable since the scientific literature itself is often fraught with the same issue and only a careful reading of a scientific article can identify whether true causation was demonstrated. For example, the peptide found in soybean, called lunasin, is currently marketed as supporting a 'healthy epigenetics.' Lunasin has been shown in *in vitro* experiments to arrest cell division and induce programmed cell death and prevent carcinogen-induced transformation of mouse skin (fibroblast) cells [36]. *In vivo*, lunasin also shows potential as its dermal application delays the appearance of tumor and their incidence in a mouse model of skin tumors. The main proposed mechanism of action of lunasin is epigenetic as several groups have described its ability to reduce core histone acetylation [37]. However, lunasin has also been shown to inhibit the activity of several intracellular kinases and that this activity is required for at least some aspects of its anti-cancer properties [38]. Thus, there is little evidence that lunasin primarily acts on cancer through epigenetic mechanisms since, for example, there is no report of counteracting its anti-cancer properties by the co-administration of a histone de-acetylase inhibitor. While lunasin's activity via epigenetic means remains a viable hypothesis, it is clear that (1) other, non-epigenetic, mechanisms may also play a role, and importantly (2) that the body of knowledge surrounding lunasin has not allowed us to move beyond the correlative stage between its impact on the epigenome and its anti-cancer properties.

Third and lastly, the public discourse on epigenetics reflect the scarcity of relevant studies demonstrating cause–effect relationships. Very few studies cited in our database demonstrate that a certain activity or exposure acts by epigenetic means insofar as: They cause detectable and consistent changes in specific epigenetic marks; there is knowledge related to their mechanism of action such as a change in the level or activity of the enzymes regulating the aforementioned epigenetic marks; and importantly, that their activity on these epigenetic marks has been experimentally demonstrated in animal models to be required for their purported health benefit. The most precise claims do use some link to science but with extrapolation rather than proper evidence. Very few claims are rooted in mechanistic, interventionist studies while a few approximate causation. For instance, the claim that a high-fat, low-carb diet can improve memory [id_779, science popularization website, information] cites a study where a metabolite, beta-hydroxybutyrate (BHB), that is elevated in a ketogenic diet, could rescue the effect of mutations in two epigenetic genes important for chromatin accessibility and implicated in the human Kabuki syndrome [39]. In a mouse model of the disease, BHB, likely *via* its histone deacetylase inhibitory activity, modulates epigenetic marks, restores their levels to normal in neurons and improves neurogenesis and memory. Thus, the claim here benefits from the fact that the disease at hand originates from dysfunctional epigenetic factors, thus clearly identifying an epigenetic cause from the start. It is important to note, however, that from all the experiments described in the scientific literature, there seems to be no advantage for a ketogenic diet or BHB supplementation on neurogenesis or memory for non-mutant animals. Thus, the claim can be misleading since there is no evidence that a high-fat, low-carb diet would be beneficial for unaffected people.

Conclusion

Although new advances in epigenetics research are being reported to the public at an accelerating rate, few scholars have investigated the forms, reasons and consequences of the public circulation of epigenetics. This article is a first exploitation of an original media database for the 2013–17 period. It shows that the public image of epigenetics is more homogeneous than the one described for the scientific community. Whereas scientists are still divided about the nature of its relationship with genetics, epigenetics in the public sphere appears to be mostly built through strong opposition lines to genetics. Here, epigenetics is all about novelty, openness and most importantly reversibility through individual action, as the importance of the personal development lexical class observed in our textual analysis shows.

This article has also emphasized the supposed or expected social utility of epigenetics. The public circulation of epigenetics findings is closely connected to an overall promise of empowerment: Regardless of the sometimes controversial nature of environmental epigenetics, its public exposition seems to nourish the belief that any individual, whatever the social condition may be, will be able to 'take control,' to act positively on his or her life course through small but critical actions and decisions. Who among us has not wanted, at one time or another, to believe in such a promise? The article highlights how this promise of control is accompanied by the development of a vast array of products and services. New markets are spreading in different areas—skincare, wellbeing, nutrition, fertility coaching, etc.—with a specific attention to pregnant women.

The centrality of this 'consumerist' and frequently naively 'optimistic' perception of epigenetics in our database should not lead to embracing an overly simplistic view of the social and political circulation of epigenetics. What makes epigenetics exciting for most social scientists is its potentially ambivalent sociopolitical uses that can be perceived, depending on the circumstances, as positive or negative. As has been shown by recent socio-historical studies [40, 41], epigenetics—as genetics before it—can turn out to be an 'opportunity' or a 'burden,' a 'progressive knowledge' or 'principle of social discrimination.'

Finally, this article underlines the emergence of a new scientific culture. The majority of the knowledge claims present in our database are poorly informed about current research in epigenetics. Still, it is already possible to describe the early 'scientification' of the cultural appropriation of epigenetics through the widespread use of biological references, and through a small but significant number of knowledge claims which give an accurate account of recent research in epigenetics. Significantly, some of the overinterpretations of results, rather than due to a public distortion of epigenetics, mirror pitfalls in the scientific field itself. Finally, our database is just as rich in what it brings to view—high expectations and the nascent stage of a new culture—as in what is absent from it, in particular the acknowledgment of the social determinants of individual 'healthy' behaviors, and awareness of the difficulty of personal decisions to be a credible substitute for informed political decisions about

most kinds of environmental exposures, various toxic chemicals, airborne pollutants, pesticides and other harmful substances.

Our analysis, as any future exploitation of our database, can inform the scientific community about the current and evolving state of the public representation of epigenetics and help it frame outreach activities. It highlights places where distorted images of epigenetics that convey over-expectations may warrant correction, or a presentation of results that will not fuel them. This article is also an invitation to more collaborations between life and social scientists. Studying the social dissemination of a new research area such as epigenetics requires the combination of multiple fields of expertise. This multidisciplinary approach adds to our understanding of the new questions raised by the public dissemination of epigenetics, in comparison to those raised by genetics in the late 1980s or early 1990s, and it helps shed light on the complex interactions between the nature of postgenomic science and the evolving perception of its social relevance.

Acknowledgements

This work was supported by the French National Research Agency in the framework of the 'Investissements d'avenir' program (ANR-15-IDEX-02). Patrick Allard (ISG, Epicenter, UCLA) and Anne Le Goff (ISG, Epicenter, UCLA) were funded by the Templeton foundation. The authors thank Bill Montrose for his careful reading of the first draft of this article.

Conflict of interest statement. None declared.

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